Small-scale Forestry (2014) 13:501–514
DOI 10.1007/s11842-014-9267-5

RESEARCH PAPER

Estimation of Production Cost of Pure Plant Oils and Biodiesels from Karanja, Palm and Soapnut Plantations Through Financial Analysis

Jibanananda Jena · Rahul Dev Misra

Accepted: 19 April 2014 / Published online: 10 May 2014

Abstract The plantations of oil-bearing trees and conversion of their vegetable oils to biodiesel have positive impacts on the agricultural, rural and national economies as well as being a partial solution to the energy scarcity. In India, many oil-bearing tree plantations including jatropha, karanja, palm and polong have already been established, mostly at a small farm' levels with direct and indirect assistance from the private and government sectors. In this study, the private financial sustainability of karanja, palm and soapnut plantations has been studied through private discounted cash flow analysis and an attempt has been made to evaluate the production cost of these pure plant oils (PPOs) and biodiesels from an Indian prospective. The net present value from karanja, palm and soapnut plantations is estimated at INR 226000/ha, INR 261000/ha and INR 173000/ha respectively, for a plantation project life of 15 years under average yield conditions. The estimated payback period on the investment is 6 years for karanja plantation and 7 years for palm and soapnut plantations. The production costs of PPO and biodiesels for karanja, palm and soapnut are estimated to be INR 47.33/kg and INR 51.44/kg, INR 42.80/kg and INR 46.67/kg, and INR 45.66/kg and INR 49.68/kg, respectively. The estimated production costs of these PPO crops indicate that they can compete financially with petrodiesel to meet the mandatory blending requirement in transportation sector of India.

Keywords Environment · India · NPV · Petrodiesel · Payback period

J. Jena (✉) · R. D. Misra
Mechanical Engineering Department, National Institute of Technology, Silchar 788010, Assam, India
e-mail: jivanjena@gmail.com

R. D. Misra
e-mail: misrardnits@gmail.com

Introduction

The Earth's limited reserves of fossil fuel have been a matter of global concern because these are under threat of depletion due to over exploitation. Deteriorating environmental conditions have become an issue of ever increasing worldwide public concern. Presently, the combustion of fossil fuels is one of the major global sources of carbon dioxide (CO_2) as well as nitrogen oxides (NOx) emissions. Further, increased fossil fuel prices, and declining fossil oil reserves around the world put the energy security at the top of energy agenda in many countries, especially oil importing countries. These problems have led to an innovative global search for renewable energy sources. Some alternatives, particularly renewable energy options, have been discovered and developed, including production and use of biofuels. Increased use of biofuels may provide a partial solution to both energy resource depletion and greenhouse gas emissions, by contributing to the displacement of fossil oil use (Mathys 2008).

With rise in economic growth and living standards of people in India, the demand for energy is increasing exponentially (World watch Institute 2008). In India the domestic production of crude petroleum oil has remained more or less stagnant over recent years and meets only 25 % of national energy requirement. Approximately 70 % of energy required by India is met through imports of 146 million metric tonnes of fossil oil and coal, costing the country nearly $90 billion in 2011–2012 (Shinoj et al. 2011). The remaining 5 % of energy required is met through nuclear and solar power. In 2012, India registered the highest increase in biofuel production in recent years. With the addition of 0.151 million tonnes of plant oil production, India registered a 75 % increase in PPO production relative to 2011. India held only 0.4 % share of the global energy production in 2012. However, this is likely to increase as the National Biofuel Mission of India prepares for a change in its biofuel mandate from its current E5 (5 % ethanol content in the fuel supply) to E10 (10 % ethanol content in the fuel supply) by 2017 and 20 % thereafter to reduce the quantity of imported diesel (Shinoj et al. 2011). Biodiesel in India is mostly produced from PPOs extracted from oil-bearing seeds. But the cultivation practices of oil-bearing trees and their financial analysis are not backed by adequate research.

The interest in oil-bearing tree plantations and conversion of their pure plant oils (PPOs) to biodiesel is increasing throughout India over time. These plantations not only reduce import needs but also help address unemployment and poverty in rural communities (Brittaine and Lutaladio 2010). For any agricultural activity to be adopted or expanded, besides other factors the adoption depends critically on investment profitability. In the case of oil-bearing tree plantations, some uncertainties involved include quality of plantation management, fertility of soil, availability of labour, and access to irrigation. These uncertainties should be reduced in making the plantations profitable at the farm level (Rethinam 1992).

This study analyzes the overall financial viability of three types of oil-bearing tree plantations in India—karanja, palm and soapnut—through financial analysis. Karanja non-edible and palm edible oil bearing plants have been selected because they are established sources of biofuels. The soapnut non-edible oil plant is selected because, as noted by Misra and Murthy (2011), it has recently been established as

one of the promising biofuel sources. Further, an attempt has been made to evaluate the production cost of karanja, palm and soapnut PPOs and biodiesels.

The Study Area

The National Policy on Biofuels of India permits cultivation of karanja, palm and soapnut in wastelands only (GoI 2008). According to the National Remote Sensing Agency (NRSA) of India, the total wasteland available in four states of India (Odisha, Jharkhand, Madhya Pradesh and Chhatishgarh) was 86 km^2 in 2003 (Wastelands Atlas of India 2005). Out of this total wasteland available in the four states, all the three species can readily be grown on about 75 % on the land area, which includes wasteland with or without scrub, and underutilized or degraded forest land. Because of the availability of wasteland, in recent years private organizations including D1 Williamson Magor Biofuel Limited (D1WMBF Ltd) and Smriti Herbs and Biofuel Farm have been actively engaged in expansion of karanja, palm and soapnut plantations with small growers in the region. Growers are engaged in the feedstock production as the first component of biofuel value chain. The expansion may be a high-risk enterprise with the possibility of over-estimation of yield and profitability. Thorough financial investigation is needed which takes into account the costs and revenue resulting from karanja, palm and soapnut plantations, to reducing financial risk and influence adoption and expansion of these oil-bearing plantations. Some studies have indicated sound profitability of oil-bearing tree plantations in general but studies specifically on karanja, palm and soapnut plantations are required, given the ever increasing use of PPOs and biodiesels in vehicle engines.

Research Methods

A survey was conducted in which primary data were collected from 240 growers of karanja, palm and soapnut through uniformly designed structured interview schedule during March 2012 to April 2013. Focus group discussions (FGDs) were also carried out to collect in-depth information. From each state, one district (Keonjhar district in Odisha, Jabalpur in Madhya Pradesh, Bastar district in Chhattisgarh, and Madhubani district in Bihar) and then two villages within it were selected randomly. The selection of the villages was made through purposive sampling, based upon the intensity of plantations, and random sampling was used to select 80 karanja growing farmers, 80 palm growing farmers, and 80 soapnut growing farmers from eight villages (two villages from each state).The secondary data for the analysis were collected from published literature, websites and the National Bank for Agriculture and Rural Development (NABARD), National Oilseed and Vegetable Oils Development Board (NOVOD), and Rural Development Department (RDD) of India. Data on the production of PPOs and biodiesels from the selected oil-seeds were obtained from the biodiesel plant run by Chhatishgarh Biodiesel Development Authority, India (CBDA) at Raipur.

A financial analysis was conducted to evaluate the production of biodiesel from karanja, palm and soapnut PPOs. A project life of 15 years was adopted, although the plantations will continue to produce for longer than this. For smallholder investments, it is common to use the opportunity cost of equity capital as the discount rate. One indicator would be the interest rate which could be earned from the alternative of investing the money in private finance or depositing the money in the bank at lower risk. Thus, a constant price analysis with real discount rate of 6.5 % (after removal of the inflation component) has been selected for the present financial analysis, as suggested by Shinoj et al. (2010).

The financial performance of karanja, palm and soapnut plantations has been evaluated in terms of NPV, internal rate of return (IRR) and payback period. The annual net cash flows for production of soapnut, palm fresh fruit and karanja seeds have been evaluated considering the establishment, operation and maintenance costs of each type of the plantation.

Establishment Cost

The establishment cost of PPO plantations includes the costs of seedlings, labour, organic fertilizer (farmyard manure), site preparation, digging of holes, and planting of trees. The plant nursery costs are included in the oil production projects. These include the cost in soil preparation, soil bag fillings, watering the bagged seedlings (polybags), machinery and labour used, and maintenance of seedlings for up to 2 years. The plant nursery costs are included in the oil production projects. Mainly three types of energy inputs are involved in plant nurseries, namely energy inputs in machinery, irrigation, and the energy associated with manpower. The recommended number of seedlings per hectare of karanja (Khandelwal and Chauhan 2013) and soapnut plantations varies between 500 and 650 (DFOL 1996), and for palm plantations between 140 and 220 (Basiron 2007). In the financial analysis, a planting rate of 500 seedlings per hectare is assumed for karanja and soapnut plantations (a spacing of 5 m $\times$ 4 m), and 156/ha for palm plantations (8 m $\times$ 8 m). The survival rate for all the three species is assumed to be 90 % and the growth period before production is 4 years, following Owolarafe and Arumughan (2007) and Kureel et al. (2008). The first harvesting is assumed to commence at the end of the fifth year after planting. The average establishment costs per hectare for all three species in the Indian cultivation scenario are presented in Tables 1, 2 and 3.

The per hectare average establishment cost of karanja and soapnut plantations are assumed to be equal in the financial analyses. This is because of same number of plants are chosen for one hectare of cultivation. The establishment cost is found to be INR 14120, which includes the costs on seedling (INR 5120/ha), labour (INR 5250/ha), and Farmyard manure FYM (INR 3750/ha). The per hectare average establishment cost of palm plantations is found to be INR 18070, which includes the cost on seedling (INR 10320/ha), labour (INR 3000/ha) and FYM (INR 4750/ha). The labour cost for karanja and soapnut plantations comprises costs of land preparation (34 %), hole digging (47 %) and planting (19 %). For palm plantations the labour cost is distributed as: land preparation (29 %), hole digging (43 %) and planting (28 %).

Table 1 Costs and returns of karanja plantation for a project life of 15 years in (INR/ha)

Cost and return component	Year 0	Year 1	Year 2	Year 3	Year 4	Year 6	Year 8	Year 12	Year 15
1. Establishment cost	14,120	0	0	0	0	0	0	0	0
Nursery	5,120	0	0	0	0	0	0	0	0
Labour cost on various operation	5,250	0	0	0	0	0	0	0	0
Land preparation	1,800	0	0	0	0	0	0	0	0
Digging	2,500	0	0	0	0	0	0	0	0
Planting	950	0	0	0	0	0	0	0	0
FYM	3,750	0	0	0	0	0	0	0	0
2. Operation and maintenance cost	5,300	5,675	4,625	4,075	1,700	1,700	1,975	0	0
Fertilizer	2,000	2,000	2,000	2,000	1,000	1,000	1,000	0	0
Irrigation	2,100	2,100	1,400	700	700	700	700	0	0
Pesticide	600	500	500	500	0	0	0	0	0
Weeding and cleaning of soil	600	600	725	600	0	0	0	0	0
Pruning	0	275	0	275	0	0	275	0	0
Replanting	0	200	0	0	0	0	0	0	0
3. Harvesting and seed separation cost	0	0	0	0	4,800	4,800	8,000	12,000	12,000
4. Total cost on establishment, maintenance and harvesting	19,420	5,675	4,625	4,075	6,500	6,500	9,975	12,000	12,000
5. Production of seed on (kg/ha)	0	0	0	0	1,200	1,200	2,000	3,000	3,000
6. Gross income	0	0	0	0	18,000	18,000	30,000	45,000	45,000
7. Net income	NA	−5,675	−4,625	−4,075	11,500	11,500	20,225	33,000	33,000
8. Cumulative cash flow	−19,420	−25,095	−29,720	−33,795	−22,295	705	33,780	127,455	226,455

End-of-year timing is assumed for costs and returns, the end of year 0 being the time of project commencement

Table 2 Costs and returns of palm plantation for a project life of 15 years in (INR/ha)

Cost and return component	Year 0	Year 1	Year 2	Year 3	Year 4	Year 7	Year 8	Year 12	Year 15
1. Establishment cost	18,070	0	0	0	0	0	0	0	0
Nursery	10,320	0	0	0	0	0	0	0	0
Labour cost on various operation	3,000	0	0	0	0	0	0	0	0
Land preparation	870	0	0	0	0	0	0	0	0
Digging	1,290	0	0	0	0	0	0	0	0
Planting	840	0	0	0	0	0	0	0	0
FYM and fertilizer	4,750	0	0	0	0	0	0	0	0
2. Operation and maintenance cost	11,250	7,105	5,200	4,075	2,500	2,500	2,800	2,800	2,500
Fertilizer	3,000	2,000	2,000	1,500	1,000	1,000	1,000	1,000	1,000
Irrigation	7,000	3,500	1,700	1,200	1,000	1,000	1,000	1,000	1,000
Pesticide	650	500	500	500	500	500	500	500	500
Weeding and cleaning of soil	600	630	725	600	0	0	0	0	0
Pruning	0	275	275	275	0	0	300	300	0
Replanting	0	200	0	0	0	0	0	0	0
3. Harvesting cost	0	0	0	0	2,500	2,500	4,500	6,500	6,500
4. Total cost on establishment, maintenance and harvesting	29,320	7,105	5,200	4,075	5,000	5,000	7,300	9,300	9,000
5. Production of FFB on (T/ha)	0	0	0	0	5	6	9	13	13
6. Production of fresh fruit (T/ha)					3	3.6	5.4	7.8	7.8
7. Gross income	0	0	0	0	18,000	21,600	32,400	46,800	46,800
8. Net income	NA	−7,105	−5,200	−4,075	13,000	16,600	25,100	37,500	37,800
9. Cumulative cash flow	−29,320	−36,425	−41,625	−45,700	−32,700	9,900	35,000	147,800	261,600

Table 3 Costs and returns of soapnut plantation for a project life of 15 years in (INR/ha)

Cost and return component	Year 0	Year 1	Year 2	Year 3	Year 4	Year 7	Year 8	Year 12	Year 15
1. Establishment cost	14,320	0	0	0	0	0	0	0	0
Nursery	5,120	0	0	0	0	0	0	0	0
Labor cost on various operation	5,250	0	0	0	0	0	0	0	0
Land preparation	1,800	0	0	0	0	0	0	0	0
Digging	2,500	0	0	0	0	0	0	0	0
Planting	950	0	0	0	0	0	0	0	0
FYM	3,950	0	0	0	0	0	0	0	0
2. Operation and maintenance cost	4,100	3,975	3,625	3,075	1,700	1,700	1,975	0	0
Fertilizer	1,500	1,000	1,000	1,000	1,000	1,000	1,000	0	0
Irrigation	1,400	1,400	1,400	700	700	700	700	0	0
Pesticide	600	500	500	500	0	0	0	0	0
Weeding and cleaning of soil	600	600	725	600	0	0	0	0	0
Pruning	0	275	0	275	0	0	275	0	0
Replanting	0	200	0	0	0	0	0	0	0
3. Harvesting and seed separation cost	0	0	0	0	4,000	4,000	7,200	10,000	10,000
4. Total cost on establishment, maintenance and harvesting	18,420	3,975	3,625	3,075	5,700	5,700	9,175	10,000	10,000
5. Production of seed on (kg/ha)	0	0	0	0	1,000	1,000	1,800	2,500	2,500
6. Gross income	0	0	0	0	14,500	14,500	26,100	40,000	40,000
7. Net income	NA	−3,975	−3,625	−3,075	8,800	8,800	16,925	21,500	21,500
8. Cumulative cash flow	−18,420	−22,395	−26,020	−29,095	−20,295	6,105	23,030	109,030	173,530

Operation and Maintenance Cost

Operation and maintenance costs of karanja, soapnut and palm plantations include the costs associated with post-planting management operations. These operations include soil working, weeding, FYM and organic fertilizer application, pruning, and application of insecticides and pesticides (Scott et al. 2008). In India, soil working, pruning, weeding and infilling are the major plantation operations. The major component of cost in these operations is the cost on labour. However, these costs vary between sites because the method of plantation management and scale of planting vary. The expenditure on operation and maintenance per hectare of all three species are presented in Tables 1, 2 and 3.

Following Kureel et al. (2008), three irrigations in both year 1 and year 2 then 1/year up to year 10 have been assumed. In the case of soapnut plantation, two irrigations in the first and third year and one from year from year 4 to 10 are assumed, as recommended by DFOL (1996) and Yadav and Singh (2010). Palm plantations have a particularly high water requirement, needing about 1,800 mm of rainfall well distributed over the entire year. The annual rainfall of most of the areas where plant oils are grown is about 1,200–1,400 mm, which is less than the requirement for rapid growth of palm trees (Owolarafe and Arumughan 2007).

Pruning is necessary to ensure branching and thus high production, as well as to restrict all three species to an appropriate size and shape. However, the time interval, frequency and procedure of pruning varies between regions, depending on the growth rate of the trees. Weeding is the other important post planting management operation, which decreases with increase in age of the plants. Infilling is assumed in the present study.

Other Costs Associated with Plant Oil Production

The other associated costs in the oil seed plantations of karanja and soapnut include the costs on harvesting, seed separation, transport, and marketing of seeds. Harvesting and seed separation are performed manually. Assuming an 8-h working day, a person can harvest 25 kg of decorticated (seeds removed from shell) karanja or soapnut seeds in 1 day. Considering the possibility of harvesting 100 kg of decorticated karanja or soapnut seeds in four man-days, the per hectare annual average labour costs on harvesting has been calculated at a daily wage rate of INR 100 as presented in Tables 1, 2 and 3. As per the available literature, under average rainfall conditions, the expected annual average seed yield of karanja from the tenth year onwards varies from 3.5 to 6 tonnes/ha, depending soil fertility, viz. poor or average (NABARD Consultancy Services 2007). The present analysis presumes the per hectare annual average karanja seed yield from the tenth year onwards of plantations is 3 tonnes with an average seed yield of 6.5 kg/tree and per hectare annual average soapnut seed yield from the tenth year onwards of 2.5 tonnes based on a yield of 5 kg/tree.

The other associated costs in case of palm plantations include harvesting of the fresh fruit bunch (FFB), and transportation and marketing of fresh fruits. Assuming palm tree height in the range of 3–4 m, two persons are required for harvesting up to

400 kg of FFB, carrying the FFBs to the transportation collection point, and also separating the fruits from the branches. Owolarafe and Arumughan (2007) reported that, under average irrigation and maintenance levels, the expected annual FFB yield per hectare of palm from the tenth year onwards varies between 12 and 15 tonnes. It is evident from Tables 1, 2 and 3 that the harvesting cost is another important cost component in these plantations.

Financial Returns from Karanja, Soapnut and Palm Plantations

The financial return per hectare of karanja, soapnut and palm plantations for a period of 15 years calculated on a basis of production quantity are presented in Tables 1, 2 and 3. The returns over the years show that karanja, soapnut and palm plantation generate income from the fifth year onwards. However, the plants are not mature enough to realize the production fully even when 10 years old. The data reported in Tables 1, 2 and 3 indicate that production increases from year 8 onwards and it is stabilized by the tenth year. It is found that the costs of production of karanja and soapnut seed are INR 8.70/kg and INR 9.30/kg respectively, and that of palm fresh fruit is INR 2145/tonne. The selling prices have been decided after a thorough market study. The selling prices of karanja seed and soapnut seed have been kept as INR 15/kg and INR 16/kg respectively, which is less than the present market retail price. The selling price of palm fresh fruit is assumed to be INR 6000/tonne. The annual revenue from karanja, soapnut and palm plantations is found to be INR 15660, INR 11830 and INR 17400 respectively.

A payback period as 6 years is found for karanja, and 7 years for soapnut and palm plantations. The profitability of these oilseeds crops cannot be compared with that of other plantation crops because these plantations are promoted either on barren lands or forest lands which is not suitable for other crops. Much of the land used in India for the three biofuel crops is reasonably fertile land and the climate suitable, so the assumed yields may be conservative.

The NPV, IRR and payback period of the karanja, soapnut and palm plantations are calculated and presented in Table 4. It is found that the IRRs from karanja, palm and soapnut plantations are 13.52, 14.86 and 12.12 % respectively, indicating reasonable financial viability. The financial indicators indicate that the plantation projects with the selected oil seeds are acceptable and could provide a consistent return to the planters. The highest NPV is found for palm plantation.

Cost of Production of PPOs and Biodiesels

In most of the oil bearing tree growing areas, modern processing plants have not yet been constructed in sufficient numbers. The government aims to attract private investment to build this capacity but the private parties are concerned about potential risks because of uncertainty regarding the supply of sufficient feedstock and the present market demand for biodiesel. Further, the unavailability of feed stock processing units is making the farmers to scale back their production and this poses threat to even the existing processing units.

Table 4 Financial parameters of karanja, palm and soapnut plantations

Parameters	Karanja	Palm	Soapnut
NPV (INR/ha/year)	90,628	111,947	78,168
IRR (%)	13.52	14.86	12.12
Payback period (years)	6	7	7

Table 5 Cost of the oil extraction plant

Description of item	Cost (INR 1000)
Land	30
Factory shed and store room	50
Machineries and equipment, oil expeller complete with 20 hp Motor	160
Tools and accessories	12
Electrification and installation	10
Misc. fixed assets	10
Preliminary and pre-operative expense	5
Total	277

Table 6 Cost of the biodiesel plant

Description of items	Cost (INR in thousands)
Land	30
Factory shed and store room (250 m^2 at INR150/m^2)	37.5
Machineries and equipment (reactor with boiler and water pump)	175
Electrification and installation	10
Total	252.5

Raw material processing infrastructure is one of the key requirements in the oilseed-based biodiesel value chain and is presently a major constraint holding back the development of the biodiesel sector in India. The cost of production of biodiesel will increase substantially if the units have low throughput. The problem becomes worse with increase in the price of seeds and fresh fruits due to the involvement of middlemen, and from higher transportation costs when these products are sourced from greater distances.

In order to avoid the distance problem, the data for cost of production of PPOs and biodiesels have been taken from one biodiesel processing plant, run by Chhattisgarh Biodiesel Development Authority (CBDA) at Raipur, India. The cost of the oil extraction unit and of the biodiesel plant unit associated with production of PPOs and biodiesels are presented in Tables 5 and 6 respectively. The physical and monetary details regarding input requirement per day and corresponding production

Table 7 Estimation of karanja, palm and soapnut PPO (in INR/kg)

Cost item	Karanja		Palm		Soapnut	
	Quantity	Cost (INR)	Quantity	Cost (INR)	Quantity	Cost (INR)
Interest on fixed capital	7.5 %/annum	58/day*	7.5 %	58/day*	7.5 %	58/day*
Seeds/fresh fruit	1 tonne/day	15,000	1 tonne/day	6,000	1 tonne/day	14,500
Skilled labour	2 human/day	400	2 human/day	400	2 human/day	400
Unskilled labour	2 human/day	200	2 human/day	200	2 human/day	200
Managerial labour	1 human/day	775	1 human/day	775	1 human/day	775
Electricity	120 U	1,200	150 U	1,500	120 U	1,200
Depreciation on machinery	12 %	60	12 %	60	12 %	60
Depreciation on other assets	5 %	6	5 %	6	5 %	6
Total cost		17,699		9,099		17,199
Oil mill by product						
Seed oil cake/palm shell waste	700 kg at INR 5	3,500	300 kg at INR 1	300	700 kg	3,500
Palm kernel	–	–	75 kg at INR 10	750	–	–
Revenue from byproduct		3,500		1,050		3,500
Net cost incurred (total cost − revenue from byproduct)		14,199		8,049		13,641
Cost of PPO/kg = net cost/total kg of crude oil		47.33		42.80		45.66

* Fixed capital estimates are taken from Table 5

Table 8 Estimation of karanja, palm and soapnut biodiesels in (INR/kg)

Cost item	Karanja		Palm		Soapnut	
	Quantity	Cost (INR)	Quantity	Cost (INR)	Quantity	Cost (INR)
Interest on fixed capital	7.5 %/annum	53/day*	7.5 %	53/day*	7.5 %	53/day*
Quantity of PPO	1 tonne/day	47,330	1 tonne/day	42,800	1 tonne/day	45,660
Unskilled labour	3 human/day	300	3 human/day	300	3 human/day	300
Skilled labour	1 human/day	220	1 human/day	220	1 human/day	220
Administrative labour	1 human/day	650	1 human/day	650	1 human/day	650
Chemicals						
Methanol	65 L	685	65 L	685	65 L	685
Sodium hydroxide	2.5 kg	75	2.5 kg	75	2.5 kg	75
Electricity	50 U	500	50 U	500	50 U	500
Depreciation on machinery	12 %	60	12 %	60	12 %	60
Total cost		49,873		45,343		48,203
Revenue from byproduct						
Glycerol at INR 20/kg	50 kg	1,000	50 kg	1,000	50 kg	1,000
Net cost incurred (total cost − revenue from by product)		48,873		44,343		47,203
Recovery of biodiesel from 1 tonne of PPOs	950 kg		950 kg		950 kg	
Net cost/total production of biodiesel (INR/kg)		51.44		46.67		49.68

* Fixed capital values are taken from Table 6

of PPOs and biodiesels with other byproducts in the biodiesel plant are presented separately in Tables 7 and 8 respectively. The cost of PPO and biodiesels for karanja, palm, and soapnut are estimated to be INR 47.33/kg and INR 51.44/kg, INR 42.80/kg and INR 46.67/kg, and INR 45.66/kg and INR 49.68/kg, respectively. The biodiesel plant is assumed to be located where the feedstock crops are growing well, to avoid high transportation cost of raw materials. From the production cost of PPOs and biodiesels it is clear that these can compete comfortably with petroleum diesel fuel in the open market.

Conclusions

The financial analysis plantations of the three oil-bearing species—karanja, palm and soapnut—reveal that they are financially viable. The results in terms of NPV, IRR and payback period confirm that out of the three plantation types the greatest increase in the producer's net worth could be achieved with palm plantations. From the present analysis the cost of PPO and biodiesels for karanja, palm and soapnut are estimated to be INR 47.33/kg, and INR 51.44/kg, and INR 42.80/kg and INR 46.67/kg, and INR 45.66/kg, and INR 49.68/kg respectively. The above biodiesels can compete comfortably with petrodiesel only when the biodiesel plants can be grown in large plantations to gain economies of scale. This could be ensured by realizing a stable supply of feed stock through a constant production level and consistent demand of biodiesels, with glycerol as the byproduct in the market. Thus, promotion of oil-bearing tree plantations could address the issues of energy security and greenhouse gases (GHGs) emission control. Further, these plantations will be more profitable if the support from government in the form of subsidies, technical assistance and marketing assistance is made available for plantations.

References

Basiron Y (2007) Palm oil production through sustainable plantations. Eur J Lipid Sci Technol 109:289–295. doi:10.1002/ejlt.200600223

Brittaine R, Lutaladio N (2010) Jatropha: a smallholder bioenergy crop the potential for pro-poor development. Food and Agriculture Organization. Accessed on 22 June 2013. http://www.fao.org

Centre for Strategic and International Studies (CSIS) (2006) India's energy dilemma. South Asia Monitor, Washington. www.csis.org/files/media/csis/pubs/sam98.pdf. Accessed on 15 Sept 2012

D1 Willamson Magor Bio Fuel Limited (2013) www.d1wm.co.in. Assessed on 28 Nov 2013

Dharani Forestry and Orchards Limited (1996) www.soapnutworld.com. Accessed on 21 May 2013

Government of India (GoI) (2008) The National Policy on Bio-Fuel. Ministry of new and renewable energy. http://mnes.nic.in. Accessed on 29 Nov 2013

Khandelwal S, Chauhan RY (2013) Life cycle assessment of neem and karanja biodiesel: an overview. Int J ChemTech Res 5(2):659–665

Kureel RS, Singh CB, Gupta AK, Pandey A (2008) Karanja a potential source of biodiesel. National Oilseed and Vegetable oil Development Board, Ministry of Agriculture Govt. of India 2008. www.novobdboard.com. Accessed on 23 June 2013

Mathys A (2008) Assessment of the current biofuel industry in India and Canada. Thesis, submitted to Queen's University, Kingston, Ontario

Misra RD, Murthy MS (2011) Performance, emission and combustion evaluation of soapnut oil–diesel blends in a compression ignition engine. Fuel 90:2514–2518

NABARD Consultancy Services (2007) Jatropha plantation in Tripura: techno feasibility report. Tripura Regional Office, India

Owolarafe OK, Arumughan C (2007) A review of oil palm fruit plantation and production under the contract-growers scheme in Andhra Pradesh and Tamil Nadu States of India. Agric Eng Int: CIGR E J 9(4):1–18 Invited Overview, March 2007

Rethinam P (1992) History of oil palm cultivation and potential in India. Proceedings of the conference on oil palm production and technology, Kasaragod, Kerala, India, pp 7–11

Scott PT, Pregelj L, Chen N, Hadler JS, Djordjevic MA, Gresshoff PM (2008) *Pongamia pinnata*: an untapped resource for the biofuels industry of the future. Bioenergy Resour 1:2–11

Shinoj P, Raju SS, Kumar P, Msangi S, Yadav P, Thorat VS, Chaudhary KR (2010) An economic assessment along the jatropha-based biodiesel value chain in India. Agric Econ Res Rev 23(Conference Number):393–404

Shinoj P, Raju SS, Chand R, Kumar P, Msangi S (2011) Biofuels in India: future challenges. Policy Brief No. 36, National Centre for Agricultural Economics and Policy Research, New Delhi

Wastelands Atlas of India (2005) Categorywise and Districtwise Wasteland Area, Department of Land Resources, Ministry of Rural Development, Government of India and National Remote Sensing Agency, Hyderabad. http://dolr.nic.in/fwastecatg.htm. Accessed on 29 Nov 2013

World watch Institute (2008) Biofuels for transport: global potential and implication for sustainable energy and agriculture. Earthscan, West Burlington

Yadav A, Singh O (2010) Energy estimations for life cycle analysis of jatropha, neem and karanja biodiesels, a parametric study. J Power Energy 1(1):55–59